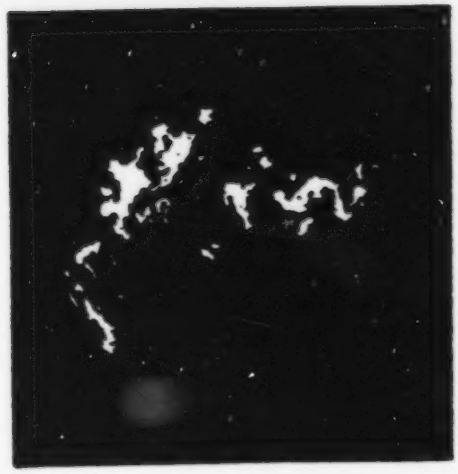
Annual Report 1983/84

Atmospheric Sciences



ALBERTA RESEARCH COUNCIL

Natural Resources Division
Atmospheric Sciences Department

Table of contents

Preface iv
Summary 1
Introduction 1
Weather modification 2
  Rain experiments 3
  Hail experiments 4
  Storm forecasting 6
  Sulfur and precipitation 6
  Snowpack augmentation 6
  Ground generators 6
  Cloud seeding 7
Applications 7
  Flow forecasting 7
  RAINSAT 8
  Consulting services-Raytheon 10
  Sulfur removal 10
  Lightning 10
Revenue and expenditures 11
Bibliography 12
Appendix 13

Figures

Figure 1. The precipitation process chain and its relation to the hailstorm and to various types of measurements 3
Figure 2. Mean ice crystal concentration within the seeding plume as a function of time for four clouds seeded with CO_2 4
Figure 3. Mean ice crystal concentration within the seeding plume as a function of time for five clouds seeded with AgI 4
Figure 4. Microphysical observations from seeding experiments conducted on 21 and 26 July 1983 5
Figure 5. A schematic vertical cross-section along leg C of the cloud system and the measured liquid water contents on 23 March 1982 7
Figure 6. The precipitation conversion efficiency of the cloud system on 23 March 1982 8
Figure 7. Overall flow of radar data 9
Figure 8. Display computer: flow of control data 9
Figure 9. Plots of visible and infrared GOES satellite imagery at 2245Z, 16 July 1980, along with CAPPI radar fields at 2 km, 3 km, 4 km and 5 km 10
Figure 10. Vertical mm cross-sections of segment-averaged sulfur dioxide concentrations, nitric oxide concentrations, mean size of ice crystals, total ice concentrations and maximum liquid water content measured at various altitudes and downwind distances from the Syncrude stack on 17 December 1983 11

Tables

Table 1. Projects of the Atmospheric Sciences Department 2

Preface

This annual report of the Atmospheric Sciences Program is for the 1983/84 fiscal year. The Atmospheric Sciences Program falls within the broader mandate of the Alberta Research Council's Natural Resources Program.

The Alberta Research Council's Atmospheric Science Program Committee and Alberta Agriculture's Advisory Committee on Weather Modification are the primary sources of advice on the general direction of research. Alberta Agriculture, Alberta Environment, Environment Canada, Raytheon Company and the Alberta Research Council provided financial support to this program during the year. Personnel of the Alberta Research Council's Atmospheric Sciences Department together with various contractors carried out the projects. It is a pleasure to acknowledge all the agencies and talented individuals who contributed to the Atmospheric Sciences Program during 1983/84.

Projects during the fiscal year investigated weather modification, hydrological applications of weather radar, short-term weather forecasting, applications of weather satellite data and the emissions from natural gas processing plants and oil sands processing plants.

Interested readers are referred to annual reports of the previous two years that, together with this report, summarize recent atmospheric sciences research at the Alberta Research Council.

R.G. Humphries
Acting Head
Atmospheric Sciences
Department

Summary

The Alberta Research Council, through its Atmospheric Sciences Department, acts as the central agency for weather modification research and operations in the province. The program is responsive to the needs and directives of Alberta Agriculture and its Advisory Committee on Weather Modification.

Research activities in weather modification during the year included:

Hailstorm seeding experiments — eleven clouds were treated in 1983. Marked seeding signatures have been observed in the seeded turrets as indicated by increased ice crystal concentrations and numbers of graupel particles. Rimed, super-cooled cloud water samples also show significant concentrations of silver only in the seeded turrets.

Rainfall seeding experiment — twenty-four clouds were treated on a random basis with dry ice, silver iodide or placebo. Increases in the ice particle concentrations and depletion of the cloud liquid water were observed in the CO_2 and AgI treated clouds. Of the 16 clouds analyzed to date, none of the untreated clouds produced radar echoes while 10 out of 11 treated clouds did, indicating particles in the treated clouds grew to precipitation sizes visible to the radar.

Research aircraft — 185.5 hours were flown in support of research activities. All the objectives outlined in the Operations Plan were met.

Storm forecasting — the synoptic index of convection (developed a few years ago) was adopted as a regional predictor of maximum intensity of convective storms.

Sulfur and precipitation — measurement of the possible effects that natural gas processing plant emissions have on convective clouds continued.

Snowpack — 3, two-week observation programs were conducted using the research aircraft. Cloud liquid water not being converted to precipitation was observed on several occasions, supporting earlier observation that some potential for augmenting winter snowfalls over the southern Rockies does exist.

Ground generator assessment — in the continuing assessment of the ability of ground-based generators to seed summer convective clouds, the research aircraft flew 21 missions in the ground generator seeding area. Narrow plumes of high concentrations of ice nuclei were detected on occasions, but these plumes comprised less than a few percent of the total research aircraft flight track within the target area. No evidence of uniform widespread "airmass" seeding has been found.

Cloud seeding — four aircraft conducted cloud seeding operations in the area from Red Deer to Calgary. The aircraft flew 183 cloud seeding missions totalling 422 flight hours. Hail activity within the project area was relatively light as hail reports were 26 percent below average. Major hail storms (100 hail reports or more) occurred on only 3 days in the northern project area and on 2 days in the southern area. The major storm of the year was on 12 July (300 reports) with larger than golfball hail reported in both the north and south target areas.

Flow forecasting — Alberta River Forecast Center of Alberta Environment was provided with radar-derived measurements of rainfall in "real-time" using radar data from the Research Council's weather radars located at the Red Deer Airport. A fully operational system is contemplated for the summer of 1984.

RAINSAT — designed to improve "day-1" forecasting of mesoscale events through the use of satellite data, the Canadian Atmospheric Environment Service and the Research Council demonstrated that GOES data could be used over the prairies to identify severe storms. Good qualitative agreement was obtained between cold (and bright) clouds as seen by the satellite and regions of high radar reflectivity.

Consulting services — a radar meteorologist was sent to Raytheon in Massachusetts for discussions and participation in meetings regarding meteorological applications of the Next Generation of Weather Radar (NEXRAD) for the United States.

Sulfur removal — a cooperative project with Alberta Environment was conducted during December 1983 in the Fort McMurray area. Data were gathered on the dispersion and transformation of sulfur and nitrogen oxides emitted from the oil sands plants. Emissions were followed as far as 71 km downwind from the source stack.

Introduction

This report summarizes the status and results of the various projects and activities of the Atmospheric Sciences Program for the fiscal year 1983/84. All of the program activities were carried out by the staff of the Atmospheric Sciences Department of the Alberta Research Council. The department was also involved in activities and other programs related to new initiatives of the Alberta Research Council in the area of Joint Ventures and Advanced Technologies that are not reported in this document.

Research in hail suppression, rain augmentation and snow augmentation was again the major effort. About 90 percent of the department's budget and resources were devoted to these studies. During the past few years, there has been an attempt to diversify into other areas of research. So far the efforts have been modest (only 10 percent of total budget) but significant in their impact. These diversification projects include the Flow Forecasting Project jointly sponsored by Alberta Environment and the Alberta Research Council, the RAINSAT Project sponsored by the Canadian Atmospheric Environment Service, the Sulfur Removal Project jointly sponsored by Alberta Environment and the Alberta Research Council, and Consulting Services to Raytheon in the United States in support of the design of the next generation of weather radar for the United States.

Table 1. Projects of the Atmospheric Sciences Department

Project	Principal Investigator	Objectives	Major objectives
Hail and rain Physical assessment	M. English	- to assess whether and how cloud seeding influences precipitation processes in convective clouds	- single-cloud seeding experiments using research a/c
Quantitative assessment	R. Humphries	- to develop design and measurement criteria to evaluate weather experiments	- radar measurement of precipitation - statistical design - weather prediction
Ground generator	F. Robitaille	- to evaluate ground-based cloud seeding methods	- ground generator seeding program - laboratory investigations
Cloud seeding	D. Deibert	- to conduct operational hailstorm seeding program	- field operations
Sulfur and precipitation	M. English	- to investigate effects of gas plant emissions on precipitation processes	- airborne measurements in plumes - statistical studies
Snow	F. Robitaille	- to assess the potential for snowpack augmentation in mountains	- observation (via research a/c) of cloud to precipitation conversion processes in clouds over the Rocky Mountains
Sulfur removal	M. English	- to document the transport and transformation of pollutants	- airborne measurements and sampling of particulates and gases in AOSERP area
RAINSAT	R. Humphries	- to provide understanding of mechanisms causing mesoscale precipitation	- determine usefulness of GOES data over Prairies and combine with forecast synoptic index
Flow forecasting	R. Humphries	- to provide real-time radar-derived rainfall measurements to a remote site	- develop a minicomputer system communication a remote radar computer system (in Penhold) to obtain and display rainfall measurements
Raytheon	R. Humphries	- to provide consulting services	- attend Raytheon advisory meetings and review documents and plans concerning NEXRAD
Lightning	G. Goyer	- to assess use of radar to forecast lightning	- correlate radar observations of thunderstorms with power outage data. Stratify according to meteorological conditions

Weather modification

The potential benefits to agricultural production in Alberta from increased water supplies are enormous. As demands for water within the province continue to grow, so does the importance of being able to develop an ability to augment precipitation through cloud seeding. The weather modification program at Alberta Research Council is addressing this issue from a physical/experimental basis directed toward increasing rainfall, suppressing hail and increasing snowfall. Research in these areas is being pursued through the various projects in table 1.

Modifying precipitation hypotheses are often stated in simple or general terms. Such statements ignore the many complex steps involved, and make assumptions portraying a simple solution.

The precipitation process chain, which describes the growth of precipitation in clouds, has now been conceptualized as a series of interlocking steps for each precipitation type (figure 1). By identifying these steps (or links), developing sub-hypothesis for each of them, and addressing each link one at a time, notable progress is being made in weather modification research.

The research emphasizes studies of a cloud's physical and meteorological processes through specific cloud seeding experiments. The conduct of these experiments involves the use of several technologies; radars, laser measuring systems, computers and so on. These are described more fully in the annual field program reports.

Rain experiments

The most encouraging (and exciting) results of cloud seeding experiments yet carried out by the Alberta Research Council are those from single-cloud seeding trials on cumulus clouds. The experiments are designed to determine the effects of seeding on precipitation growth processes in cumulus clouds (to produce rain) and to determine the most effective seeding technique. The clouds were specifically selected because they were not raining, contained few or no ice crystals and had tops that were near the -10°C level.

Having selected this narrow range of cloud conditions for experimental purposes, twenty-four clouds were treated in 1983 on a random basis with dry ice, silver iodide or not treated (placebo). The physical conditions inside the clouds, both before and after treatment, were measured by the cloud physics research aircraft.

Increases in ice particle concentrations and depletion of the cloud liquid water were observed in the treated clouds. Microphysical differences in the silver iodide and the dry ice seeded clouds were also observed. Preliminary analysis indicates that the dry ice seeded clouds produced higher ice crystal concentrations and depleted the liquid water more rapidly than the clouds seeded with silver iodide. The evolution of ice crystals inside the treated clouds following seeding are shown in figures 2 and 3. Ice crystals in the non-treated clouds remained very low averaging less than 1.2 per litre and never exceeding 5 per litre.

In addition, of the 16 clouds analyzed to date, none of the untreated clouds produced radar echoes while 10 out of 11 of the treated clouds did produce echoes, indicating particles in these clouds did grow to precipitation sizes visible by the radar. The initial echoes of the treated clouds were also shaped dif-

Links in the precipitation process chain	Type of measurement
1. Synoptic environment 2. Cloud environment	A. Environmental measurements
3. Cloud initiation 4. Hail initiation	B. Cloud physics aircraft measurements
5. Hail growth 6. Hail fall	C. Radar observations
7. Hail on the ground	D. Surface precipitation measurements

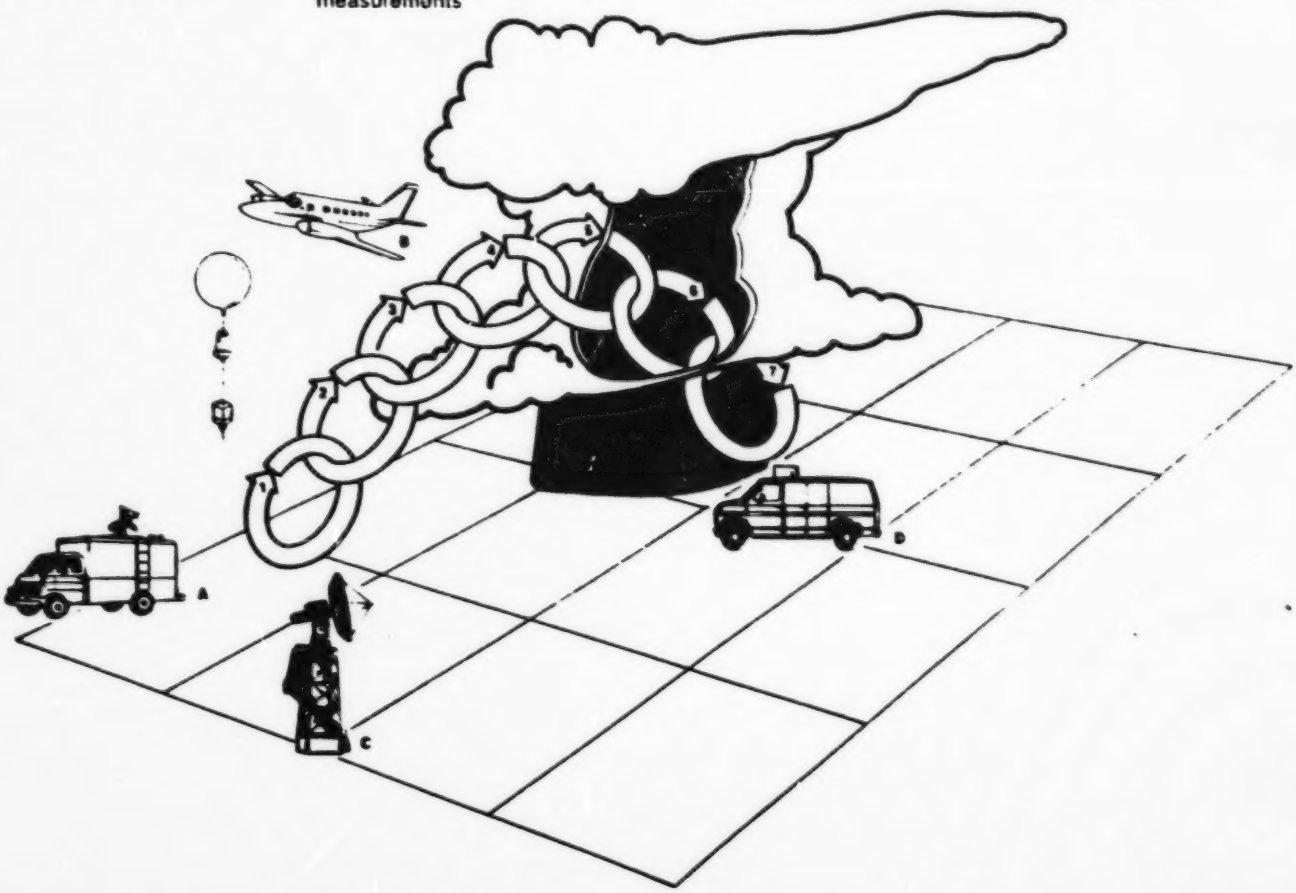


Figure 1. The precipitation process chain and its relation to the hailstorm and to various types of measurements. The macroscale links of synoptic environment and cloud environment are investigated by means of temperature, humidity and wind measurements ahead of the storm. Droplet and ice crystal initiation processes (cloud initiation and hail initiation links) are investigated primarily through in situ research aircraft cloud physics measurements in the new growth zone. In the mature storm, the hail growth and hail fall links are studied primarily through radar observations. Finally, hail on the ground is investigated through precipitation sampling.

ferently from echoes usually observed from small showers. The treated cloud echoes were elongated horizontally in the direction of the seeding aircraft pass, while normal echoes tend to be more circular with considerably greater vertical structure.

Seeding experiments to define the limits of the "seeding window" are planned. Numerical modelling studies and seeding tests using different seeding rates are planned to determine the most effective seeding rate for various cloud conditions. A remaining task will be to determine the frequency of occurrence of these types of clouds in various regions of the province.

Hail experiments

Hailstorm seeding expriments, which are being conducted to determine the effects of seeding on clouds producing hail, are similar to the rain seeding experiments, except that the experimental clouds are associated with, and in close proximity to, a hailstorm. The close proximity of a severe storm to the experimental clouds makes these experiments much more complex and difficult. Nonetheless, 11 clouds were treated in 1983 in a random scheme with silver iodide, low dry ice, high dry ice or placebo.

The hailstorm seeding experiments involve treating individual cloud turrets (feeder clouds) in the new growth zone of hailstorms, which are thought to be the primary source of hail embryos in most storms, and documenting the effects of the treatment. The goal of the experiments is to identify an ensemble of precipitation particles originating in individual cloud turrets and to follow them through the storm to the ground. The trajectory of this ensemble of particles is determined through measurements by the cloud physics research aircraft, followed by radar observations through the main storm and ending with hail samples collected at the ground.

To date, data from only four treated clouds (associated with two different storms) have been analyzed and the analyses have concentrated on the early stages of ice particle and hail embryo growth. Marked seeding signatures have been observed in the treated clouds insofar as high ice crystal concentrations and early production of graupel is concerned (see figure 4). This is consistent with the hail suppression hypothesis which, briefly, can be stated as follows: seeding with silver iodide or dry ice makes many more ice crystals, some of which grow to become hail embryos that compete with the natural hail embryos for the available liquid water so that the size of all particles will be limited. The results obtained so far constitute fairly conclusive proof that seeding creates many more ice crystals some of which grow to become hail embryos. What remains to be determined is to what extent these "artificial" hail embryos compete with the natural hail embryos and so limit the size of hail falling on the ground. This question can only be answered by obtaining more extensive data from the mature part of the hailstorm and from data related to hail fall at the ground.

During some hailstorm seeding experiments, rimed, supercooled cloud water samples were collected from the treated clouds. These rime samples have been analyzed for silver content and some other chemical species. Rime samples from clouds treated with silver iodide were found to contain concentrations of silver considerably above background levels. Only background concentrations of silver were found in rime samples collected in cloud turrets that were not seeded with droppable silver iodide flares.

Independent of the seeding experiments, some progress has been made in quantifying hail on the ground. Earlier results have shown that hail on the ground tends to have an exponential size distribution so that the concentration of hail collected at a particular time and location on the ground can be characterized by the equation

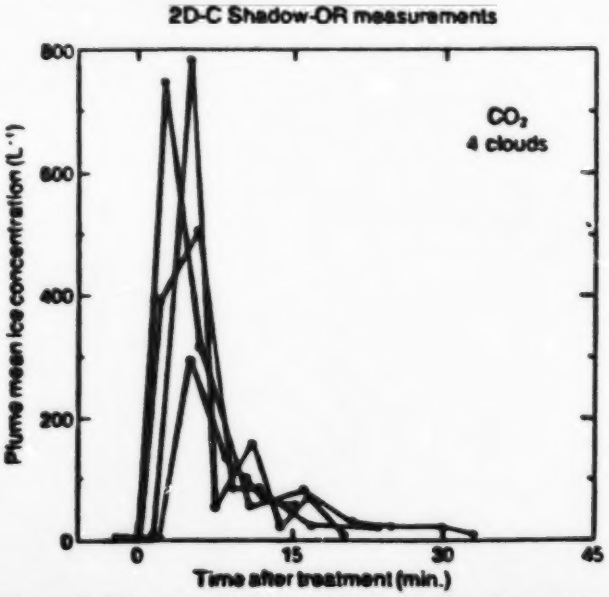


Figure 2. Mean ice crystal concentration within the seeding plume as a function of time for four clouds seeded with CO_2.

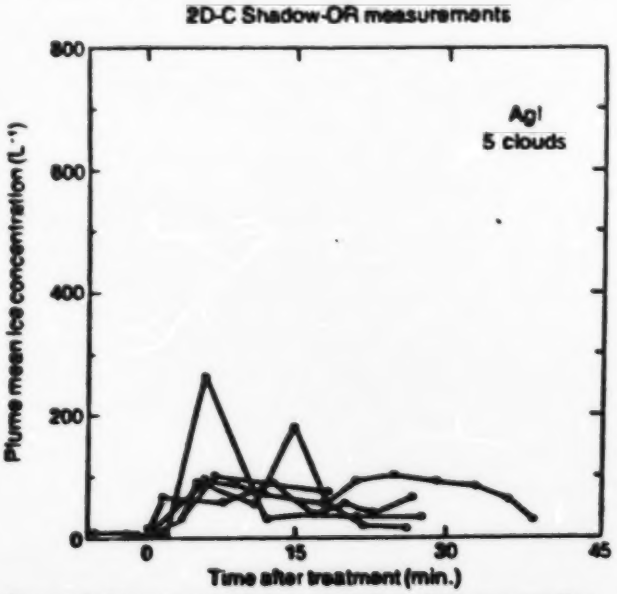


Figure 3. Mean ice crystal concentration within the seeding plume as a function of time for five clouds seeded with AgI.

$n = n_0 e^{-\lambda D}$ where n_0 and λ are constants for the particular hail sample. When all available hail samples are considered, a relationship of the form $n_0 = A\lambda^b$ exists between the constants n_0 and λ. By considering hail samples on a storm by storm basis, it was found that the exponent, b, is constant from storm to storm and has the approximate value of 4. The constant of proportionality, A, on the other hand, varies from storm to storm but seems to depend on the storm thermodynamics. In fact, predictor equations for A have been developed. Thus, we now seem to have a method of predicting the size distributions of hailstones falling on the ground from individual, unseeded storms.

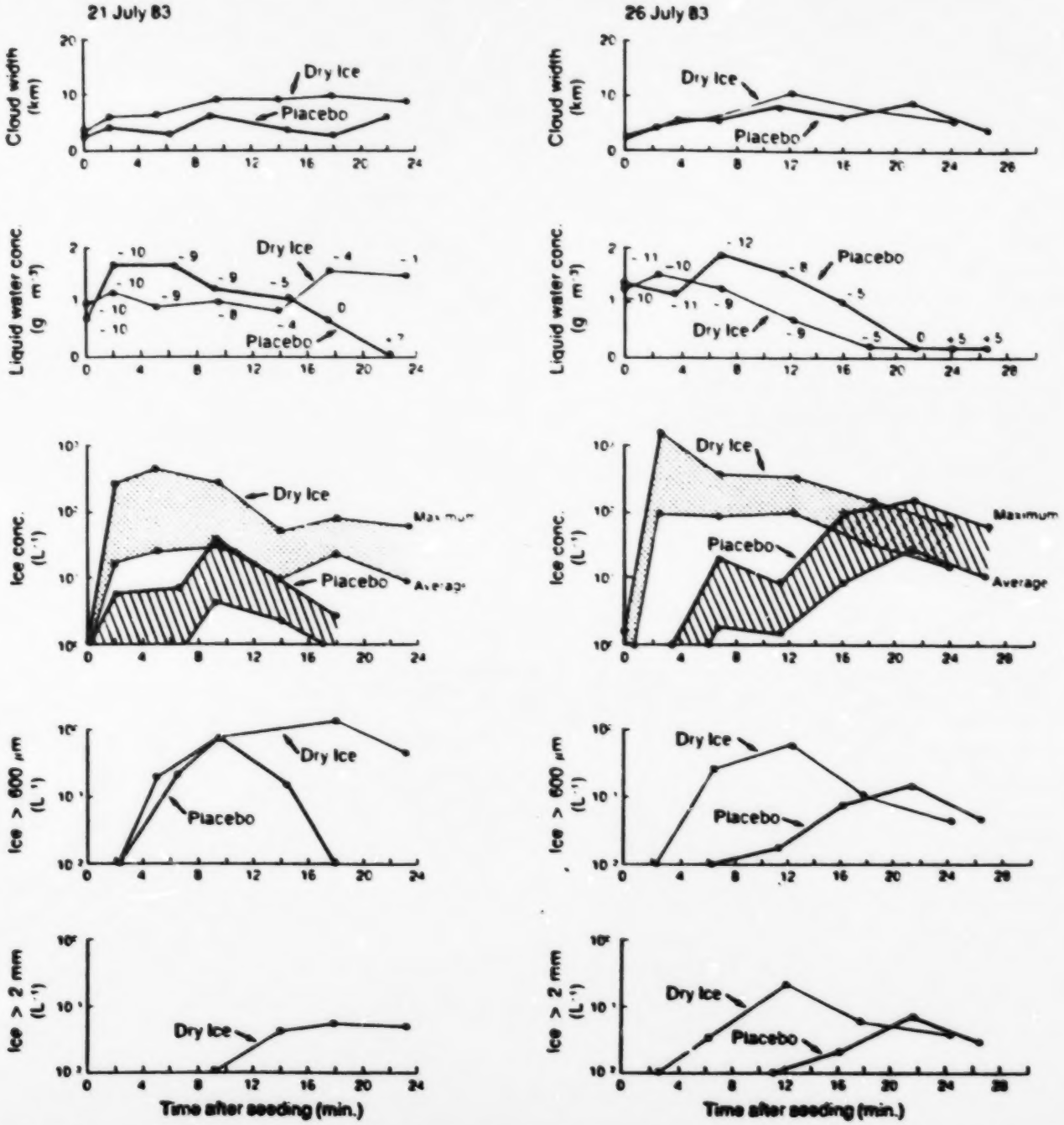


Figure 6. Microphysical observations from seeding experiments conducted on 21 and 26 July 1983. On each day, two clouds were treated: one with a high rate of dry ice and other with a placebo. The diagrams show cloud widths, mean liquid water content, mean and maximum total ice crystal concentration, mean concentration of particles greater than 600 μm in diameter and mean graupel concentration (particles greater than 2 mm in diameter) — all as a function of time after treatment. Each data point represents a cloud penetration; on the liquid water content diagram, the temperature at each penetration is in °C.

Storm forecasting

In addition to the above, the quantitative prediction of precipitation amounts from convective clouds remains an objective for the evaluation of seeding effects on an areal basis. The synoptic index of convection developed a few years ago was adapted as a regional predictor of maximum intensity of convective storms. When this information is combined with surface temperature and moisture fields (theta-e) and low-level wind flows, it is possible to make predictions of the location of initial storm development and motion. Relative storm size and life history can also be inferred. These studies have led to investigations of the effects that large-scale meteorological processes have on the convective storm environment. A hypothesis now being tested is that energy from the synoptic scale is transferred into sub-synoptic scale phenomena through regions of ascent that may help to establish the favorable atmospheric conditions for convective storm development. Some results show that sub-synoptic scale regions of ascent at low and mid levels occur at least three to six hours prior to the onset of significant convective clouds. These regions exhibit good temporal continuity for up to twenty-four hours. Their areal extent and shape appear to determine similar characteristics in subsequent convective complexes. Contoured analyses of vertical velocities compare favorably with the regions of the convective cloud complexes observed via satellite and radar. These processes are thought to be resolvable and deterministic and thus eventually predictable.

Sulfur and precipitation

Investigations into the possible effects that Alberta's natural gas processing plant emissions have on convective clouds commenced in September 1982. As only limited airborne data were obtained in 1982, these measurements were continued during the summer of 1983. The data included atmospheric aerosol concentrations, Aitken nuclei concentrations, sulfur dioxide concentrations and super-cooled cloud water samples collected on a riming rod extended from the research aircraft. Data were collected on 10 flights during 1983 with 15 riming rod samples collected for chemical analyses. No results from the analysis are yet available, however, increased concentrations of particulates were observed downwind of the processing plants. As sulfate particles are excellent condensation nuclei, these emissions may be inadvertently affecting the cloud formation processes in these areas.

Snowpack augmentation

Studies to investigate the possibility of increasing snowfall by seeding orographic clouds over the Rocky Mountains of southern Alberta were begun in 1982. During a two-week period in March 1982, research aircraft flights were made to obtain measurements of cloud hydrometeors and cloud thermodynamic structures in search of some physical evidence that a potential for winter cloud modification to increase snowfall existed. Three additional two-week field observation programs were carried out during the 1983/84 fiscal year, one in March, one in November and one in February 1984. Data from one flight in March 1982 (figures 5 and 6) show the existence of cloud liquid water that is not being converted to precipitation. Also shown is the estimated precipitation conversion efficiencies computed on the basis of the hydrometeor size distributions observed in the clouds.

Analysis is on-going. However, observations taken during each of the four field periods strengthen the notion that some potential for augmenting winter snowfalls over the mountains does exist.

A preliminary analysis of the snow climatology of the Rockies south of Banff has been completed as part of the background study. Precipitation data from a variety of sources were analyzed including data from Alberta Environment Service climate stations and snow course data from Alberta, British Columbia and Montana. The temporal, altitudinal and spatial characteristics of snowfall were examined. Peak snowfall amounts and frequency were found to occur in January for the mountain stations. Snowpack water equivalent on average reaches a maximum value in late spring. A strong correlation was found between snowfall amount and elevation. The spatial variability of snow is quite complex with maximum annual snowfall amounts occurring along the Alberta-British Columbia border regions. More detailed climatological analyses are continuing.

Ground generators

The project to assess the ability of ground-based generators to seed summer convective clouds continued in 1983. Irving P. Krick Associates of Canada Ltd. were contracted to operate a ground-based cloud seeding network south of Calgary in a normal operational mode from 20 June through 19 August using 92 generators within a network of 69 sites. Research aircraft flights were conducted through the ground generator seeding area on 21 occasions, measuring meteorological parameters and ice nuclei concentrations with an acoustical ice nucleus counter. Narrow plumes of high concentrations of ice nuclei were detected on occasions, but these plumes comprised less than a few percent of the total research aircraft flight track within the target area. No evidence of uniform widespread "airmass" seeding has been found. The research aircraft flew more often near cloud bases during the 1983 observational program than in earlier years and fewer ice nuclei were detected.

Laboratory tests were conducted at the Colorado State University cloud simulation and aerosol laboratory during the year to determine the effectiveness of the generator nuclei, nucleation mechanisms and rates of nucleation. These tests have shown that, although the nuclei generated by the coke generators were initially considered hygroscopic and likely to dissolve in warm clouds, they remained effective after entering clouds at temperatures a few degrees above freezing and subsequently rising to colder levels in the clouds.

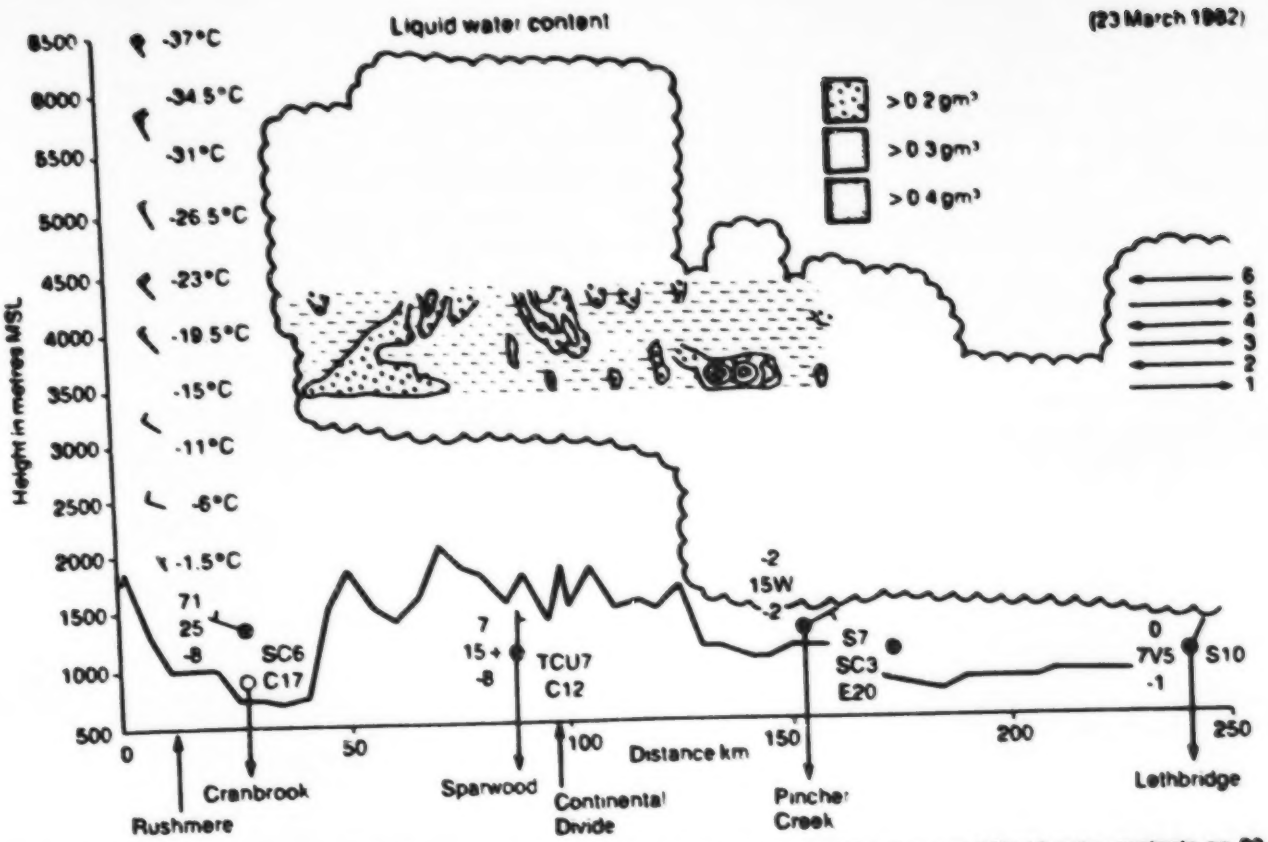


Figure 5. A schematic vertical cross-section along leg C of the cloud system and the measured liquid water contents on 23 March 1982. The liquid water contents represent 10 second averages (approximately 1 km distance) from the Johnson-Williams hot-wire probe. The vertical profile of wind (full barb equals 10 m/s) and temperatures from the mobile rawinsonde at Rushmere is located along the vertical axis. The terrain height and surface weather observations at Cranbrook, Sparwood, Pincher Creek and Lethbridge are shown along the horizontal axis. The locations and directions of the six research aircraft cloud penetrations are indicated.

Cloud seeding

The cloud seeding program conducted in the southern project area during 1983 was the same as during the 1982 summer period. Cloud top and cloud base seeding was conducted by four aircraft from 20 June to 31 August. The cloud seeding operations were contracted to INTERA Technologies Limited of Calgary. A total of 183 cloud seeding missions were flown during the season with 422 flight hours; 144 kg of silver iodide were dispersed during the season compared to 233 kg in 1982.

During the operational cloud seeding period, hail was reported in the project area on 38 days and 1935 hail reports were received. During the hail season from 1 June to 30 September, there were 45 hail days in the project area, 4 percent below the long-term average. The 1945 hail reports during the season were 26 percent below average. Major hailstorms occurred on 12, 14, 21 July and 3 August.

Applications

Flow forecasting

The goal of this project is to provide the Alberta River Forecast Center of Alberta Environment with radar-derived measurements of rainfall in "real-time." During the early fall of 1983, a prototype of this system was tested. Radar data from the Alberta Research Council's weather radars located at the Red Deer Airport were pre-processed by a minicomputer at the radar site and then transferred to Edmonton via a telephone data line. The prepared data were received in Edmonton by the Atmospheric Sciences Department's minicomputer and then transmitted to the Alberta River Forecast Center by a high-speed data line. At the center, a small minicomputer prepared color displays showing the rainfall rate within the radar coverage and accumulated rainfall amounts. In addition, printed maps and tables were prepared. Since this test, the system has been revised to optimize data processing, to provide the man-machine interaction and to modify the type of product available. Figure 7 shows the overall flow of radar

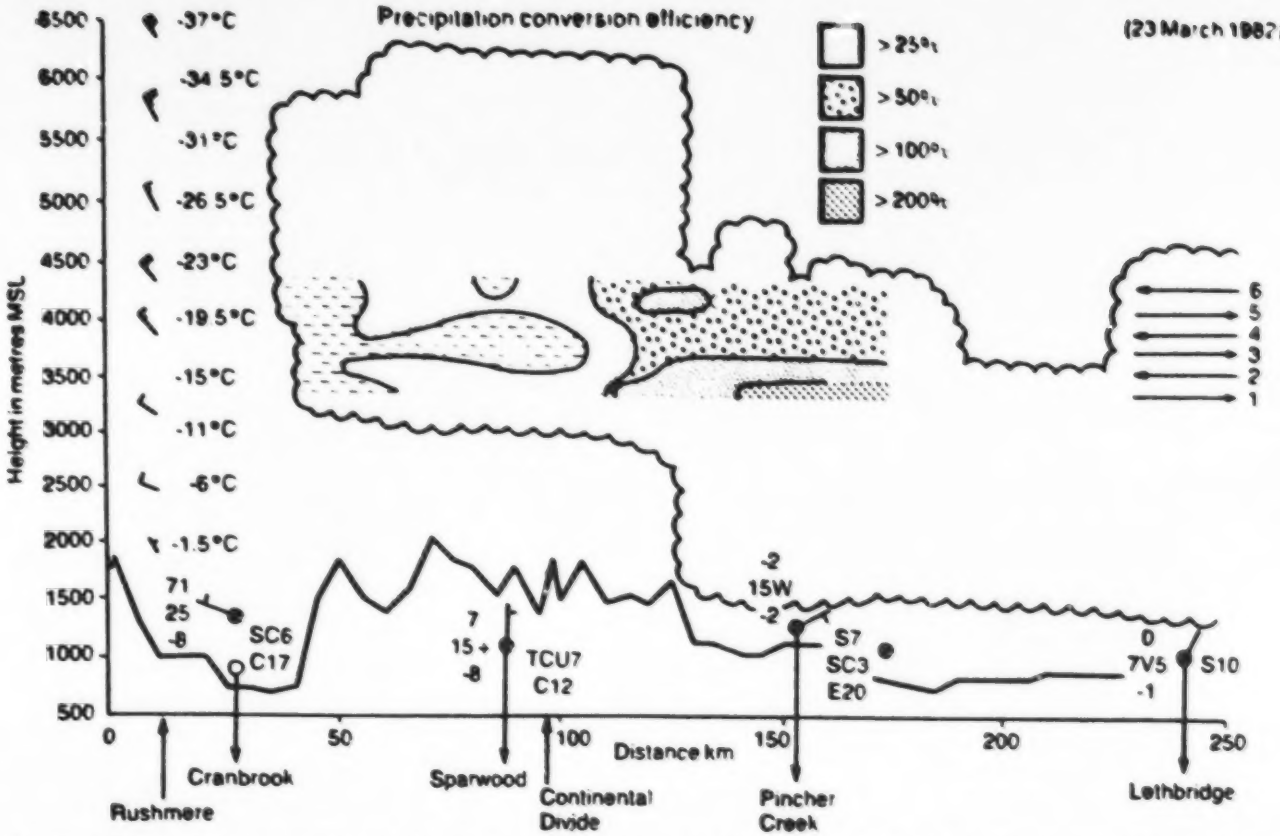


Figure 6. The precipitation conversion efficiency of the cloud system on 23 March 1982. The precipitation conversion efficiency is defined as the ratio of ice water content to total vapor condensed as determined from the environmental sounding at Rushmere

data. The left half of the diagram represents data processing that takes place at the radar site and the right half represents data processing that occurs at the Alberta River Forecast Center. The boxes represent processes that occur, such as accessing the radar data from the radar computer interface. The circles represent data files, such as prepared data. Figure 8 shows in more detail the data processing that takes place at the Alberta River Forecast Center. The system will be fully operational during the summer of 1984.

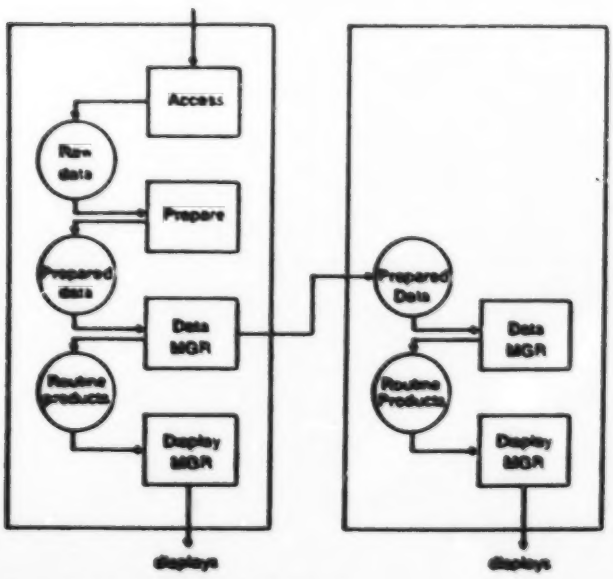


Figure 7. Overall flow of radar data

RAINSAT

The Alberta Research Council has been engaged in contractual work with the Canadian Atmospheric En-

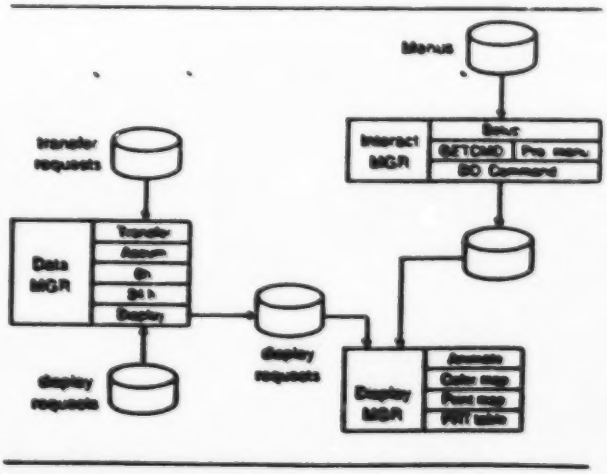


Figure 8. Display computer: flow of control data.

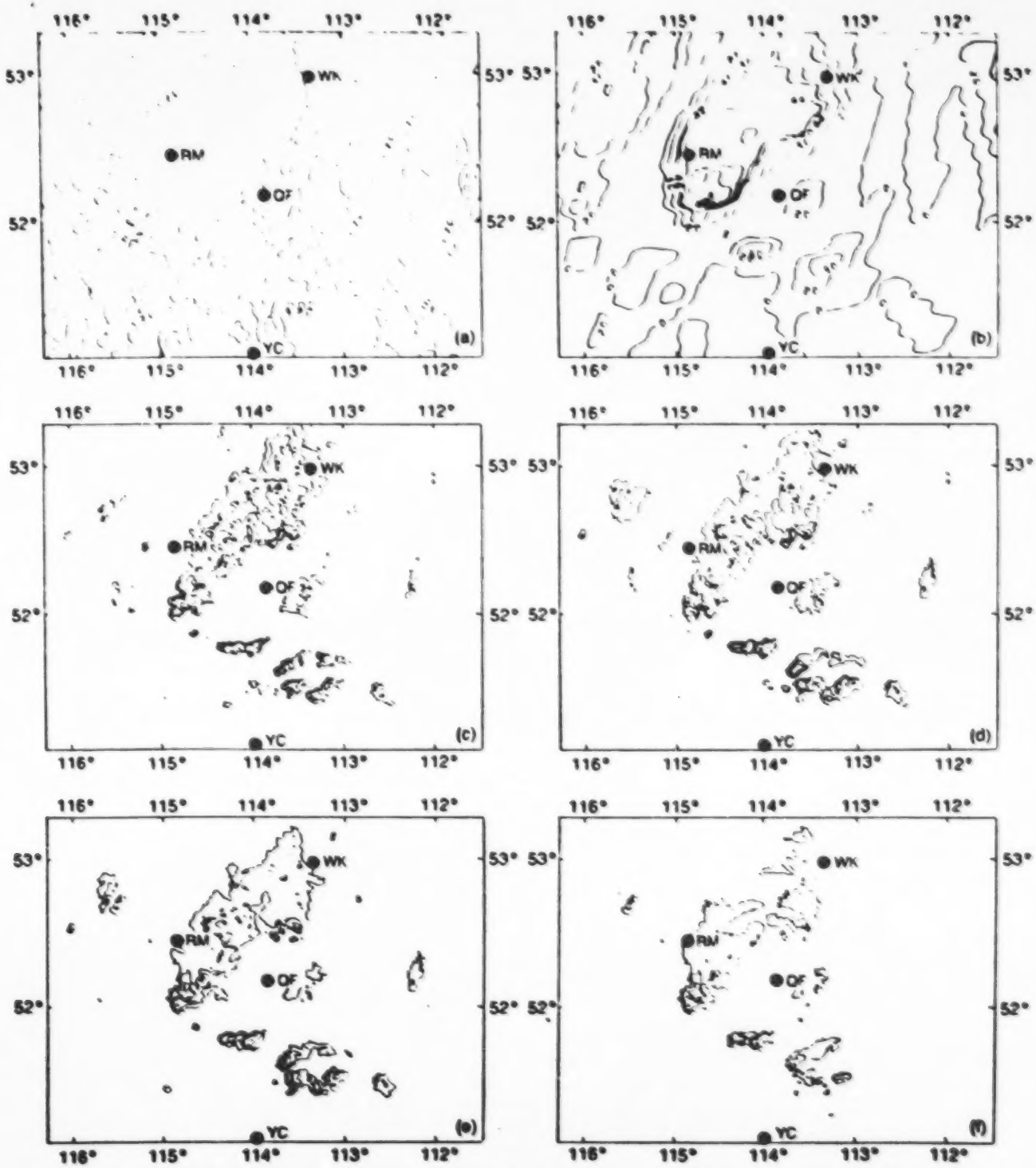


Figure 9. Plots of (a) visible and (b) infrared GOES satellite imagery at 2245Z, 16 July 1980, along with CAPPI radar fields at (c) 2 km, (d) 3 km, (e) 4 km and (f) 5 km. Minimum reflectivity contour is 20 dBz, with intervals of 10 dBz. (RM - Rocky Mountain House; OF - Red Deer Airport; WK - Wetaskiwin; YC - Calgary)

vironment Service to aid in the development of the RAINSAT Project. The main goal of RAINSAT has been to improve day-1 forecasting of mesoscale events principally through the use of GOES satellite data. The role of the Alberta Research Council in RAINSAT is to investigate the value of GOES (Geostationary Operational Environmental Satellite) data over the Canadian prairies, and to identify those factors that contribute to precipitation-producing situations during the summer months.

In this fiscal year, the second RAINSAT contract was completed. The Atmospheric Environment Service greatly assisted this project by providing software to process GOES data tapes and to produce colored maps of infrared and visible satellite data. The programs were modified to process archival data from the GOES-West satellite on Alberta Research Council computers. Two case studies demonstrated that GOES data could be used over the prairies to identify severe storms. Good qualitative agreement was obtained between cold and bright clouds as seen by the satellite and regions of high radar reflectivity (figure 9). Errors of up to 15 km in the earth-positioning of the satellite data, however, were recognized. Linear correlations between infrared and visible satellite data (spatially averaged to remove discrepancies between the pixel sizes) yielded correlations of about 0.8. Quantitative comparisons between radar CAPPI and GOES data resulted in a mean correlation of 0.5 between the 3 km CAPPI level and the infrared data.

Consulting services - Raytheon

The Raytheon Company renewed a contract for the Alberta Research Council to provide consulting services concerning the meteorological applications of the Next Generation of Weather Radar (NEXRAD) for the United States. A radar meteorologist was sent to Raytheon in Massachusetts for discussions and to participate in meetings of Raytheon's NEXRAD Advisory Committee. This service has been requested for 1984.

Sulfur removal

As part of the cooperative project with Alberta Environment to determine the dispersion and transformation of sulfur and nitrogen oxides emitted from oil sands extraction plants in the Fort McMurray area, a field program was conducted during December 1983. Airborne measurements were made under cold winter conditions during seven research flights.

Emissions were detected as far as 71 km downwind from the source stack. The atmospheric dispersion of pollutants from the Syncrude and Suncore plants appears to be greatly influenced by wind and atmospheric stability conditions. Comparisons between the observed horizontal dispersion parameters and those of the Pasquill-Gifford stability classes show that their rates of change with distance were similar, although the observed values were slightly higher than the predicted ones.

In the Syncrude plume, ice crystals that nucleated in the gaseous plume grew to precipitation size and were observed falling out of the plume and reaching the surface. Whereas in the Suncore plume, where ice nuclei concentrations seemed to be higher, the snow-out phenomenon was only noted once, when the plume height was relatively low. Figure 10 shows results from a research flight on 17 December 1983, during which ice crystals that had nucleated and grown in the plume from the Syncrude plant were observed to fall to the ground within 10 km of the stack.

The conversion rate of NO to NO_2 varied considerably from day to day, ranging from 1 percent to 5.3 percent per minute. The rate of transformation of SO_2 to SO_4 was 0 percent to 2.6 percent per hour. However, the conversion rate of nitrogen oxides to particulate nitrate was not obtained because the amount of particulate nitrate collected was below the detection limit in all cases and little or no nitric acid was found.

Lightning

A contract with the Canadian Electrical Association to investigate the feasibility of forecasting damaging lightning from radar observations has been completed. The distribution of power outages and lightning flashes around the radar echoes of thunderstorms was observed in an effort to define an intense lightning core to track and whose motion to forecast. A core, related to echo contours of high reflectivity, was defined.

The tracking and forecasting of the motion of the core was achieved with fair accuracy in post-facto analysis of data. The adaptation to real time use of the forecasting procedures is still plagued with several practical problems such as the identification and the duration of electrically active storms. Further in-depth study of the climatology of lightning and of its relationship with storm parameters seen by radar will be necessary before further progress can be achieved in the forecasting of damaging lightning.

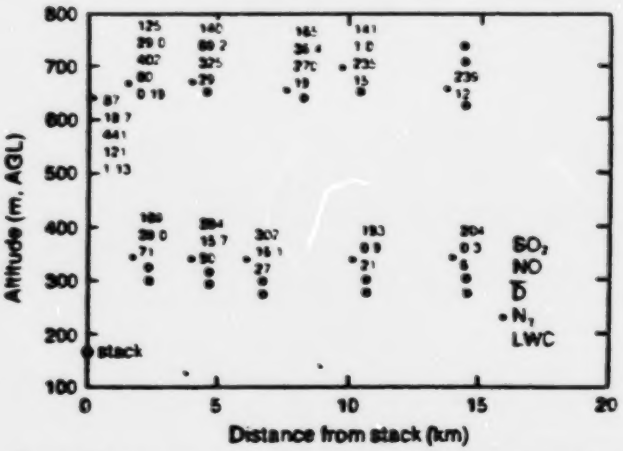
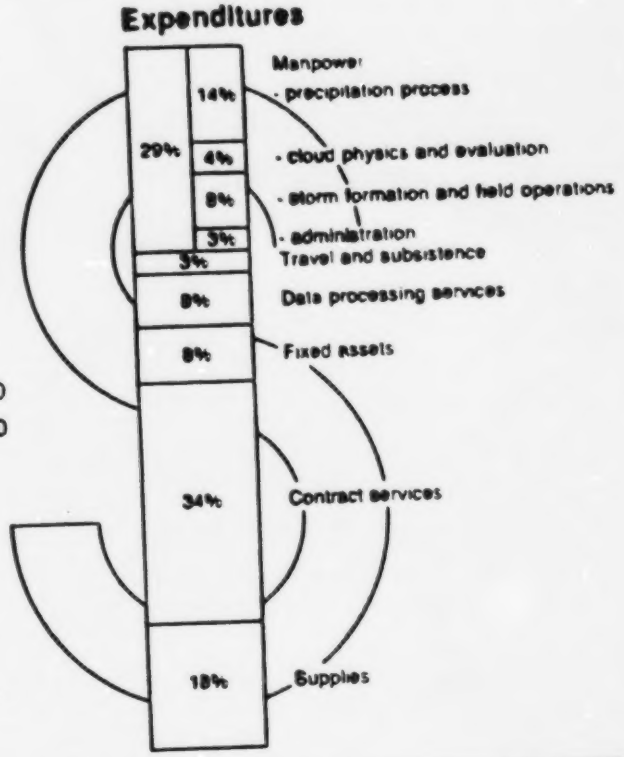


Figure 10. Vertical rnm cross-sections of segment-averaged sulfur dioxide concentrations (SO_2, in ppb), nitric oxide concentrations (NO, in ppb), mean size of ice crystals (D, in mm), total ice concentrations (N_T, in L^{-1}) and maximum liquid water content (LWC, in gm^{-3}) measured at various altitudes and downwind distances from the Syncrude stack on 17 December 1983. *indicates below minimum detectable signal.

Revenue and expenditures

Revenue ($'000)		
Alberta Research Council		1284.10
Alberta Agriculture	3779.00	
Alberta Environment (Flood forecasting)	80.00	
Alberta Environment (sulfur)	50.00	
Alberta Environment (snow)	50.00	
DDS Atmospheric Environment Service (Rainsat)	46.00	
Environmental Research Technology/Raytheon Co.	11.00	
Canadian Electrical Assoc.	80.00	
Total		4096.00
Total revenue		5380.10



Bibliography (1983/84)

Barlow, F.D., F.E. Robitaille, J.W. Mason and C.M Sackiw (1983). Snow Climatology of the Southern Canadian Rockies. (CMOS Conference 1983) [1]

Bergwall, F., R.G. Humphries and G.S. Strong (1983): The Use of Radar and a Convective Index for 1-6 Hour Regional Forecasts. (Radar Conference, Edmonton).[2]

Cheng, L. (1983): Determination of Transport, Dispersion and Transformation of SO_2 Emissions from an Oil Sands Extraction Plant. (Final report for phase I to Alberta Environment for RMD Project No. 82-08.) 152 pages.

Deibert, R.J. ed. (1983): Alberta Hail Project Field Program 1983; Edmonton: Alberta Research Council, 64 pages.

—— ed., (1983): Atmospheric Sciences Field Program and Experiment Plan 1983, Edmonton: Alberta Research Council, 47 pages.

—— (1983): Research Aircraft Alberta Hail Project; Supplement to the Proceedings of 10th Annual Meeting, North American Interstate Weather Modification Council; Lake Tahoe, September 1983.

Goyer, G.G. (1983): The Forecasting of Damaging Lightning Strokes by Radar Observations (Progress Report to CEA).

Kochtubajda, B. and E.P. Lozowski (1983): Results of a Cumulus Seeding Experi-ment. (CMOS Conference 1983).[1]

Krauss, T.W. (1983): Ice Crystal Evolution in a Hailstorm Feeder Cloud Following AgI Seeding (CMOS Conference 1983).[1]

—— F.E. Robitaille, F.D. Barlow and J. Mason (1983): Modification Potential of Orographic Cloud Systems in the Southern Canadian Rockies: Preliminary Aircraft Observations. (CMOS Conference 1983).[1]

Ramsden, J. (1983): An Approach to Software Development in a Small Group: Role of VAX/VMS Utilities. (DECUS Canadian Symposium 1983.)

Renick, J.H. (1983): Mesoscale - The Synoptic to Microscale Gap. Mesoscale Meteor. Research Planning Workshop. (CMOS, Toronto, January 1983.)

Richardson, S., B.L. Barge and R.G. Humphries (1983): Hailfall Probability Based on Radar Reflectivity. (Radar Conference 1983).[2]

—— and R. Drobig (1983): Collection and Analysis of Tipping Bucket Rain Gauge Data. Technical Memorandum.

Robitaille, F.E. (1983): Snowpack Project Operations Summary (31 March 1983), 4 pages.

—— F.D. Barlow, J.W. Mason and C.M. Sackiw (1983) Cloud Seeding by Ground Generators in Alberta Field Studies of Generator Targetting (CMOS Conference 1983).[1]

—— F.D. Barlow, J.W. Mason and C.M. Sackiw (1983): Ground Generator Assessment Project 1982 Project Report.

Rogers, D. (1983). Effects of Sideslip and Airspeed on Pressure Measurements from Aircraft; NCAR Workshop on Effects of Airflows Distinctions on Airflight Measurements, 8 pages.

Strong, G.S. (1983): Large-scale Energetics and Small-scale Convection. (CMOS Conference 1983).[1]

—— and W.D. Wilson (1983): The Synoptic Index of Convection: Application to the Fort Collins Hailstorm of 30 July 1979. (Severe Local Storms Conference 1983).

—— and W.D. Wilson (1983): The Synoptic Index of Convection: Part 1 - Evaluation of the Single-valued Synoptic Index. (CMOS Conference 1983).[1]

—— and W.D. Wilson (1983): The Synoptic Index of Convection: Part 2 - Applications of the Synoptic Index of Regional Forecasts of Convective Complexes. (CMOS Conference 1983).[1]

Torlaschi E. and R.G. Humphries (1983): Statistics of Reflectivity Gradients. (Radar Meterology Conference 1983).

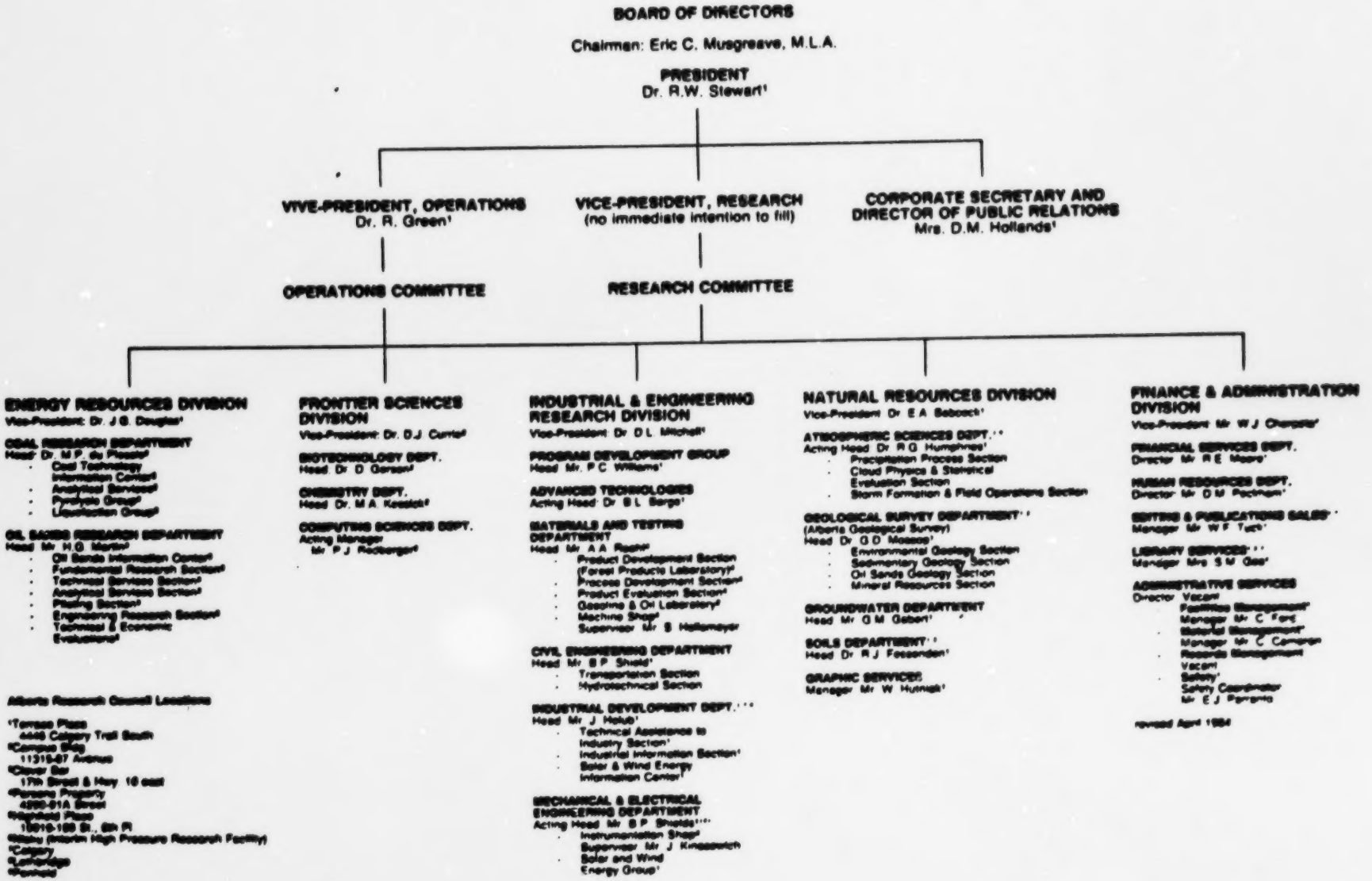
Wojtiw, L. and C. Ewing (1983): The Use of Radar to Estimate Crop Damage for Hailstorms in Alberta, Canada. (Radar Conference 1983).[2]

Wong, R.K.W. and K.D. Hage (1983): Comment on Terrain-Following Coordinates and the Hydrostatic Approximation; Journal of the Atmospheric Sciences, v. 40, no. 12, December, pp. 2875-2878.

[1](CMOS Conference 1983) - Papers presented at the 17th Annual Canadian Meteorological and Oceanographic Society Congress, Banff, Alberta May, 1983

[2](Radar Conference) - Preprints of 21st Conference on Radar Meteorology Edmonton, Alberta, September, 1983

Alberta Research Council organization chart



Atmospheric Sciences Department
Organization Chart